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An Earthquake Source Sensitivity Analysis for Tsunami Propagation in the Eastern Mediterranean

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An earthquake source parameter sensitivity analysis for tsunami propagation in the Eastern Mediterranean has been performed based on 8 August 1303 Crete and Dodecanese Islands earthquake resulting in destructive inundation in the Eastern Mediterranean. The analysis involves 23 cases describing different sets of strike, dip, rake and focal depth, while keeping the fault area and displacement, thus the magnitude, same. The main conclusions of the evaluation are drawn from the investigation of the wave height distributions at Tsunami Forecast Points (TFP).

The earthquake vs. initial tsunami source parameters comparison indicated that the maximum initial wave height values correspond in general to the changes in rake angle. No clear depth dependency is observed within the depth range considered and no strike angle dependency is observed in terms of amplitude change. Directivity sensitivity analysis indicated that for the same strike and dip, 180° shift in rake may lead to 20% change in the calculated tsunami wave height. Moreover, an approximately 10 min difference in the arrival time of the initial wave has been observed. These differences are, however, greatly reduced in the far field. The dip sensitivity analysis, performed separately for thrust and normal faulting, has both indicated that an increase in the dip angle results in the decrease of the tsunami wave amplitude in the near field approximately 40%. While a positive phase shift is observed, the period and the shape of the initial wave stays nearly the same for all dip angles at respective TFPs. These affects are, however, not observed at the far field. The resolution of the bathymetry, on the other hand, is a limiting factor for further evaluation. Four different cases were considered for the depth sensitivity indicating that within the depth ranges considered (15-60 km), the increase of the depth has only a smoothing effect on the synthetic tsunami wave height measurements at the selected TFPs. The strike sensitivity analysis showed clear phase shift with respect to the variation of the strike angles, without leading to severe variation of the initial and maximum waves at locations considered. Travel time maps for two cases corresponding to difference in the strike value (60° vs 150°) presented a more complex wave propagation for the case with 60° strike angle due to the fact that the normal of the fault plane is orthogonal to the main bathymetric structure in the region, namely the Eastern section of the Hellenic Arc between Crete and Rhodes Islands. For a given set of strike, dip and focal depth parameters, the effect of the variation in the rake angle has been evaluated in the rake sensitivity analysis. A waveform envelope composed of symmetric synthetic recordings at one TFPs could be clearly observed as a result of rake angle variations in 0-180° range. This could also lead to the conclusion that for a given magnitude (fault size and displacement), the expected maximum and minimum tsunami wave amplitudes could be evaluated as a waveform envelope rather limited to a single point of time or amplitude. The Evaluation of the initial wave arrival times follows an expected pattern controlled by the distance, wheras maximum wave arrival time distribution presents no clear pattern. Nevertheless, the distribution is rather concentrated in time domain for some TFPs. Maximum positive and minimum negative wave amplitude distributions indicates a broader range for a subgroup of TFPs, wheras for the remaining TFPs the distributions are narrow. Any deviation from the expected trend of calculating narrower ranges of amplitude distributions could be interpreted as the result o the bathymetry and focusing effects.

As similar studies conducted in the different parts of the globe indicated, the main characteristics of the tsunami propagation are unique for each basin. It should be noted, however, that the synthetic measurements obtained at the TFPs in the absence of high-resolution bathymetric data, should be considered only an overall guidance. The results indicate the importance of the accuracy of earthquake source parameters for reliable tsunami predictions and the need for high-resolution bathymetric data to be able to perform calculations with higher accuracy. On the other hand, this study did not address other parameters, such as heterogeneous slip distribution and rupture duration, which affect the tsunami initiation and propagation process.